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EVALUATION OF THE LMA™ SERIES OF WIRE ROPE TESTING INSTRUMENTS

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<p>This study evaluates some of the LMATM series instruments for the inspection of wire rope that have been developed by NDT Technologies of South Windsor, CT. These are small units, based upon the measurement of magnetic flux leakage, and appear to be well-suited for the inspection of portable cranes despite some limitations. In contrast, most devices using this method of flaw detection are large and heavy, and are only appropriate for use on mining hoists.</p> <p>Safety assurance of wire rope has long been an area of concern to the Navy. Current manual inspection methods are slow, tying up equipment for a long time, and present significant hazards to the inspector. In addition, the current wire rope inspection standards, based upon the limitations of manual inspection, are not appropriate for the newer wire rope inspection devices and must be modified if these devices are to see more widespread use.</p>				
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FOREWORD

This report documents the field evaluation of the LMA™ series of wire rope inspection instruments made by NDT Technologies of South Windsor, CT. Development of these instruments was funded in part by the small business program of the Office of Naval Research.

The Navy's interest in improved wire rope inspection devices intensified after an accident in the early 1970's in which an inspector was fatally injured using the traditional rag inspection technique, the industry standard since 1915.

The magnetic flux leakage device being developed by NDT technologies was funded for further development because its light weight and small size make it appropriate for the inspection of cranes, unlike the heavier instruments that have been developed for the large hoists used in the mining industry.

The objective of this study was to investigate the suitability of this series of instruments for inspecting the rigging of cranes. A comprehensive comparison of the performance of these instruments vis-a-vis the competition would require about two man-years of effort and is beyond the scope of the current project.

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INTRODUCTION

OBJECTIVE

The objective of this task was to evaluate the LMATM series of wire rope inspection instruments (manufactured by NDT Technologies, South Windsor, Connecticut) and to identify impediments to the more efficient inspection of wire rope. This was intended to be a modest level of effort, using only existing facilities.

WIRE ROPES

Wire ropes are fault-tolerant by design. The load is uniformly distributed among the wires, yet there is enough frictional force between the wires that, should a given wire break, its portion of the load is shared by the remaining wires near the break and also returned to it a short distance from the break. Thus a broken wire is not useless over its entire length, but only in the immediate vicinity of a break. In addition, wire ropes possess an amazing degree of flexibility for their load-bearing capability.

The existence of a few isolated breaks will not affect the serviceability of a wire rope in most applications. Indeed, individual wires are often discontinuous due to the changing of spools during manufacture. A cluster of broken wires or excessive loss of their cross-sectional area (because of wear or corrosion) can result in overloading of the remaining wires however.

Several factors make concentrated wire damage likely. Regions of overlap at the end of each layer of windings on the drum are subject to extensive work hardening and peening of the wires. Corrosion may be concentrated in certain areas, depending on use and storage. Incidental abuse can result in concentrated damage. Manufacturing defects can occur, such as from the replacement of many wire spools over a short region of the rope, resulting in a concentration of wire discontinuities. Any of these concentrations of damage or weakness is significant if the affected region is so short that the stress cannot be redistributed between breaks; thus the loss of strength is equivalent to that of several wires being broken at the same location.

The design of a rope and the type of service it sees determine the kinds of defects that are most likely to occur. Ropes are filled with grease during manufacture to allow the strands to slip against one another and to exclude moisture. Service conditions that cause the grease to be removed make the rope more susceptible to corrosion. Fiber cores hold more grease than wire cores and

are also more flexible, but if the grease is lost, they can hold more moisture as well and the resultant corrosion can be very severe on the inside, but unnoticeable on the outside.

Mine hoists and construction cranes present very different problems. Mine ropes generally have large D/d ratios (ratio of the diameter of the sheave or drum to the diameter of the rope) which minimize flexing and work hardening of the rope, with the result that fatigue-induced wire damage is relatively rare. The main enemies of mining hoist ropes are wear and, especially, corrosion, which is particularly severe in some mines because of the acidic minerals. These ropes are frequently thousands of feet long, of large diameter, and can remain in service for years as their gradual wear is monitored. The cranes used in most construction sites are designed to be more compact, so there is not room for large drums and sheaves. This results in more flexing and work hardening of the rope, and broken wires are the major concern. Broken wires may be concentrated in regions of additional insult, such as where the rope is subject to peening due to drum overlay at the end of each layer. Since drum space is at a premium on these cranes, "improved" plow-steel wire is often used. Since the higher strength of this rope is due to work hardening during its manufacture, it is already more brittle, with less margin for further in-service work hardening before becoming too brittle for service. In practice, about 70 percent to 80 percent of the broken wires occur on the inside of the cable where they are not visible. Since the wire diameters are small and the lengths are short (a few hundred feet), economics generally favor using the "improved" plow steel for its greater initial strength and replacing the cables every few months. In both applications, the wire may be subject to incidental abuse. Although replacement schedules are used in both applications, costly premature failure can still occur. On the other hand, replacement of ropes is costly in terms of materials and downtime. Inspection can minimize the cost and risk only if it properly addresses all types of damage, inside and out. Inspection access is different in the above two applications. Mining hoists generally have a large platform that can accommodate a bulky instrument, whereas space is limited on construction cranes.

Ropes experience very different service conditions when used as drag lines (for dredging), which are subject to wear and corrosion (being constantly in the mud and dirt) and which can be abused by operator technique (such as allowing the wire to go slack on the spool as the bucket is thrown out, only to be sloppily overlain as it is taken up). Entirely different service conditions are encountered by ropes used as antenna guy wires which, in being constantly exposed to the environment, are candidates for corrosion. Wind strumming causes work hardening to be concentrated at the antinodes.

Manual Inspection of Wire Ropes

The technique and standards for manual inspection of wire rope have remained unchanged since 1915. The standards were developed in response to the alarming safety record of the industry at that time. Circa 1911, with 4 accidental deaths per 1000 miners per year¹, the average miner (who started work at about age 12 and did not retire until his early sixties) faced an 18 percent probability of a fatal accident over a 50-year career.

Using this technique, the inspector holds a rag around the moving wire rope. Whenever the rag is snagged by a broken wire, the winch is stopped and that area of wire inspected.² The rope is rejected if visual inspection reveals "more than six randomly distributed broken wires on one rope lay or three broken wires in one strand in one rope lay."³ The rope can also be rejected on the basis of wear and corrosion.³

When the wire is in motion during this inspection, rope speeds of 50 feet per minute or less are recommended.² Because the speeds used for visual inspection are extremely slow, this method ties the equipment up for a considerable length of time. In one recent (1973) accident, a rope inspector in a Naval shipyard was killed by being pulled into the rigging because he could not release the rag in which he had become entangled. Since this accident, the U.S. Navy has recommended that rope speeds used during inspection be reduced even further--to 6 feet per minute or less!

The inside of the rope is not normally inspected, and the current standard⁴ attempts to compensate by allowing fewer broken wires on the outside. The likely ratio of broken internal to external wires depends on such factors as the design and service of the rope. Fiber-core rope that has lost its lubrication and picked up moisture is likely to develop extensive internal corrosion with no visible external deterioration.

Need for New Inspection Criteria

Changes in metallurgy tend to invalidate the rag-catching criteria. The rag technique was based on the fact that the soft steel wires used in the older cables would work loose and bend back as they passed through the sheaves to form "fishhooks." For greater strength, most cranes today are rigged with a hardened steel wire (improved plow steel or extra-improved plow steel), which breaks as it is bent back rather than producing fishhooks. This results in a short region of missing wire that will not catch a rag, so a region of severe damage can go unnoticed.

As mentioned above, corrosion can start on the inside of a rope, and some types of rope and use favor internal breaks. Also, changes that have been made since the 1915 standards, such as nylon-lined sheaves, reduce the wear of the outer wires. Consequently, the outer wires do not necessarily fail faster anymore. A detection method that is sensitive to internal damage and inspection standards based upon the detection of interior as well as exterior broken wires and corrosion damage are needed.

Inspection by Magnetic Flux Leakage

Magnetic flux leakage is a very sensitive means by which to detect changes of cross-sectional area of steel wire ropes, as may be due to either corrosion or to broken wires. This technology for wire rope inspection has been reviewed elsewhere.^{5,6}

The earlier instruments were termed either "AC" or "DC" instruments and sensed the flux with a simple search coil. The "AC" instruments induced a strong

alternating magnetic field along the axis of the rope and measured the flux resulting from a given current in the exciting coils. These instruments responded primarily to a change in effective cross-sectional area, and thus were indicators of wear and corrosion. The "DC" instruments applied a constant magnetic field along the axis of the rope. Usually the field was strong enough to magnetically saturate the rope. In the regions of breaks, the magnetic field would "pop out" of the saturated rope. This leakage field could be detected by a simple search coil if the rope were moved through the instrument. This instrument was particularly sensitive to broken wires. Since search coils were used to detect a DC flux, the rope had to be moved through the instrument at a certain minimum speed to obtain a satisfactory response.

The data from either of these instruments could give indications of both broken wires and loss of metallic area with proper interpretation. However, usually both an AC and a DC machine were used when reliable assessments of both loss of metallic area and of local faults were desired.

A few years ago the Research Department of Noranda Mines (Pointe Claire, Quebec) developed an instrument that combines the features of both the AC and the DC instruments. This instrument, the MagnographTM, uses permanent magnets to saturate approximately 18 inches of the wire rope and uses Hall effect sensors, which can measure a steady magnetic flow. Hall sensors within the pole faces measure the flux induced in the wire and thus the loss of metallic area without the necessity of using an alternating field. The leakage flux along the wire is sensed by Hall sensors along the rope midway between the poles and a minimal rope speed is not necessary.

The MagnographTM was designed for inspection of mine hoists, for which it does an excellent job. In this application, its size (approximately two feet long) and weight (approximately 90 to 125 pounds, depending on the size of the wire for which it is adapted) are not problems. Its size and weight, however, are genuine impediments to its use in inspecting most types of cranes.

* Manufactured by Heath and Sherwood, Inc., Markham, Ontario, Canada.

INSTRUMENTS BY NDT TECHNOLOGIES, INC.

NDT Technologies, Inc., (South Windsor, CT) has developed a series of lightweight (about 17-pound sensor head) permanent magnet instruments that are particularly well-suited for inspecting crane rigging. Each device in this series uses a search coil to detect local faults (such as broken wires) and integrates the signal for the loss-of-metallic-area indication. The wire must be run through the particular device at a speed of 50 feet per minute or more.

Because these instruments locate regions containing broken wires or with a loss of metallic area, the inspector can concentrate the visual inspection on these suspect areas. The wire is scanned for suspect areas at a rope speed of 50-1000 feet/minute, as opposed to 6 or 50 feet/minute with a rag inspection. The small size, weight, and cost (about 1/10 that of the MagnographTM) favor the use of these devices, as opposed to earlier instrumentation, for routine crane inspections. Size and weight both affect the safety of the inspector, as these devices must often be positioned on the rope while the inspector is precariously perched on the crane. (Even the drum area is typically 6 feet or so from the ground, and a fall could be serious, especially if accompanied by an instrument weighing over 100 pounds.)

NDT Technologies, in developing this series of compact instruments, designed each one to be as light as possible for the designated maximum wire size. The smallest is the LMA-75, which can handle up to 0.75-inch-diameter wire ropes. The LMA-125, LMA-175, and LMA-225 are designed to inspect up to 1.25-, 1.75-, and 2.25-inch-diameter wire ropes, respectively. Each instrument comes with a set of rope guides for smaller diameter wire ropes.

Normally, the data from these instruments are recorded by a dual-channel chart recorder which, for the more recent models, is an ASTRO-MED Model -2.* It uses heat-sensitive paper, which saves the operator the distraction of attending to ink problems. This recorder is equipped with two event-marker pens, one which produces a mark each second and another which is used either to indicate the count of a footage wheel or to indicate flaws that exceed a threshold. (An audible alarm can also be elected for flaws exceeding that threshold.)

A tape recorder interface has recently been developed that records all of the data on ordinary audio-quality cassettes. Data can be recorded on tape with the chart recorder in use or absent. The gain and offset can be adjusted on later

*ASTRO-MED, Inc., W. Warwick, RI

playback into the chart recorder. If proper attention is paid to dynamic range and calibration, the operator is spared making multiple runs to adjust the gain and offset for best display while at the test site. This is important because space is usually cramped at the test location, the environment may be adverse to instruments and to people, and finally, the crane (or hoist) and its operator are being diverted from productive work.

EVALUATION OF THE NDT TECHNOLOGIES INSTRUMENTS

The LMA-125 was evaluated on a continuous section of wire rope using the test track at NDT Technologies, Inc. This test track continuously moves the rope through the instrument at a speed that can be adjusted. As with most test tracks, the rope cannot be tensioned to the typical working loads, which would require heavier sheaves and a hydraulic ram or weights.

The test rope was 0.75-inch-diameter, 6 x 19 plow-steel rope Type S (seal) with a fiber core. This was a new rope in which defects were simulated by placing lengths of identical wire in the rope. (It is difficult to remove a section of wire without disturbing the lay of the rope unless the rope can be subsequently loaded to working tension.) Wires of 5, 15, 25, 70, and 100 mm were taped on the surface along the lay of the rope. A 70-mm-long wire was carefully buried in the strands. These modifications simulated missing lengths of wire, with the sign of the response being reversed. Extended loss of metallic area was simulated by an 18-inch-long piece of wire taped along the lay.

Figures 1A and 1B show the local fault and the loss-of-metallic-area signals for these defects. All of these defects are clearly indicated both on the local fault and on the loss-of-metallic-area channel. In this rope, the "rope noise" (background due to the texture of the rope) is well below the indication of a single missing wire. The sensitivity to the 70-mm defect is approximately the same whether it is buried or on the surface. The local fault indication is seen to be of opposite polarity at the beginning and at the end of the defect, both of which trigger the flaw indication at the bottom trace since the threshold has been set appropriately. (The flaw indication ignores the sign of the local fault response.)

This data gives confidence as to the detectability of a gap as small as 5 mm in a single wire. The rope noise of this rope is well below the indication of a single missing wire. The loss-of-metallic-area channel has more than adequate sensitivity. Baseline drift is a problem, however. Even this short record shows a slight drift; in 13 feet of travel, the baseline of the LMA channel shifts by a fifth of the indication of a single missing wire. This problem has been noted on instruments of other manufacturers.

The tape recorder interface faithfully reproduces the data as can be seen by comparing Figure 1B, which is the playback of a recorded signal, with Figure 1A, which is recorded directly from the LMA-125. On playback, the scales and offsets could have been adjusted to suit the operator's needs. The data quality is maintained and is independent of recorder gain since an fm modulation scheme is employed at the interface.

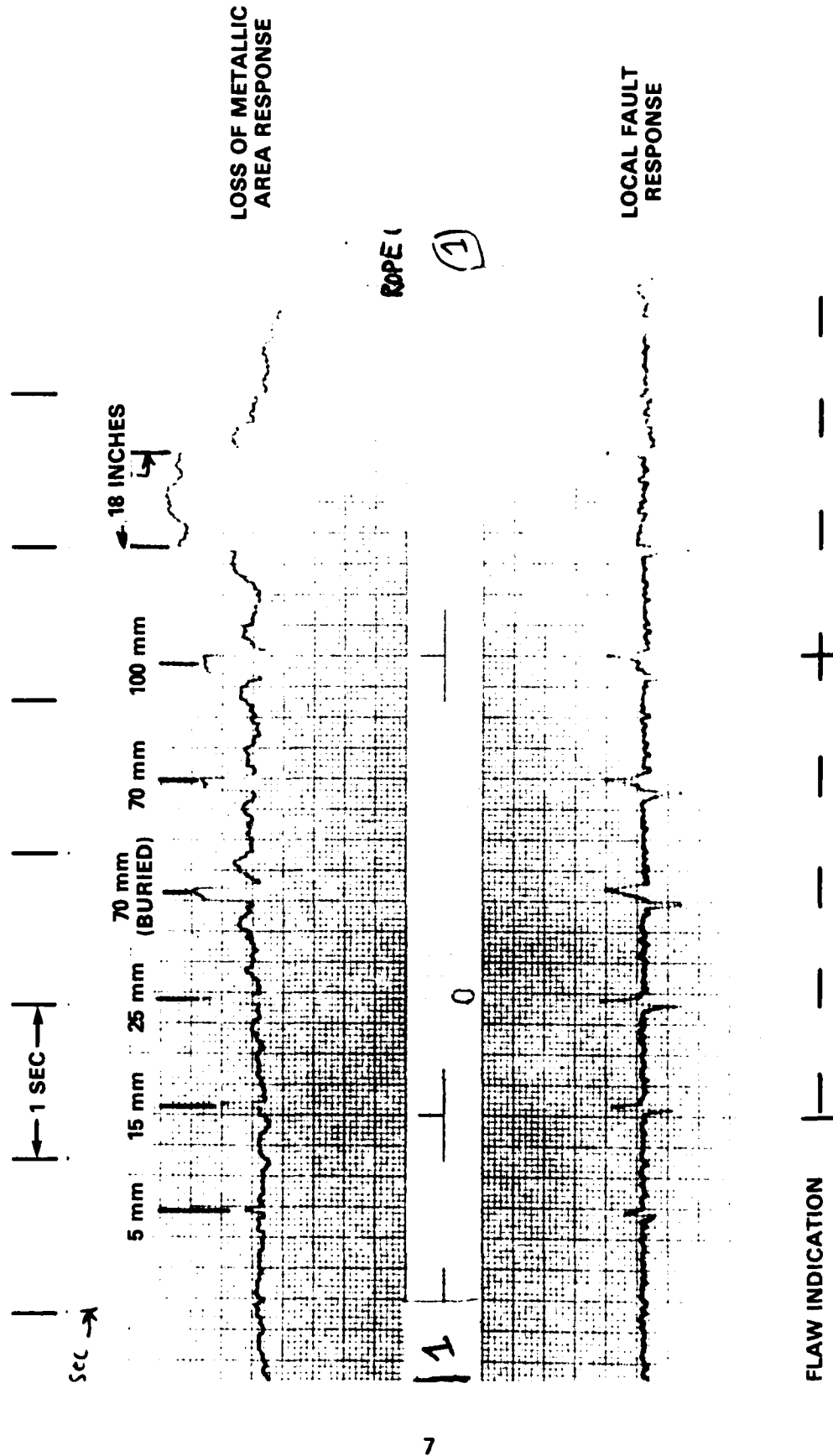
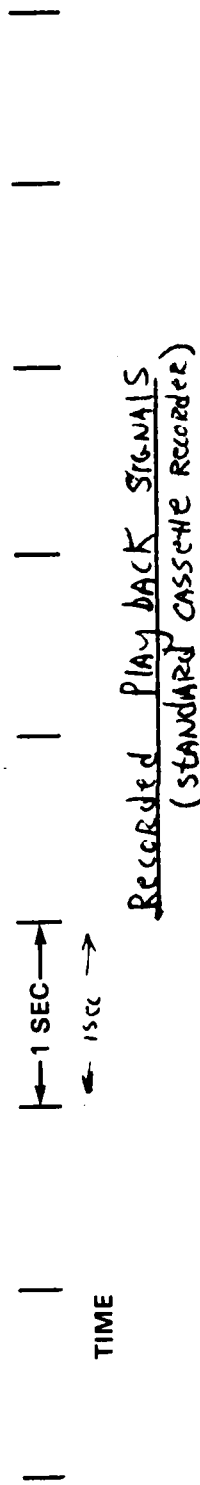


FIGURE 1A. RESPONSE OF LMA-125 TO SIMULATED DEFECTS IN A 0.75-INCH-DIAMETER, 6 x 19 FLOW-STEEL ROPE ON A TEST TRACK (DIRECTLY RECORDED DATA)



LOSS OF METALLIC
AREA RESPONSE

(A)

(A)

mm/sec

LOCAL FAULT
RESPONSE

FLAW INDICATION

FIGURE 1B. RESPONSE OF LMA-125 TO SIMULATED DEFECTS IN A 0.75-INCH-DIAMETER, 6 x 19
PLOW-STEEL ROPE ON A TEST TRACK (DATA PLAYED BACK
FROM MAGNETIC CASSETTE)

Evaluation of the LMA-175 on Construction Cranes with In-Service Ropes

A test of the NDT Technologies LMA-175 instrument was conducted on the boom lifting cable of a MANITOWOK 4100 crawler crane at a construction site. The rope was about 3/4 of the way through its replacement cycle, so a few broken wires (from fatigue) were to be expected in the length of cable inspected. Three broken wires were indicated, one being clearly visible on the outside, one almost buried, and the third probably on an inside wire (where it would be missed by a visual inspection). The wire was not corroded or severely worn (less than 1 percent area loss), and the loss-of-metallic-area reading indicated correspondingly small changes. During the test a few "fishhooked" wires were noted visually that did not give an indication noticeably above the "rope noise" on the machine.

Tests were also conducted using the LMA-75 on a PETTIBONE 50TK crane at Port Hueneme, California. It was equipped with a 5/8-inch, 6 x 25 IWRC rope, rigged in a 6-part line. This crane is shown in Figure 2. The actual testing is shown in Figures 3 to 5. The only load was the ball and hook. The rope was in fair shape, and about 12 indications were noted in around 400 feet of rope. The drum diameter was smaller than on the MANITOWOK crane and about 20 to 30 percent of the indications proved to be external, as expected. Unfortunately, the rope was still in active service and the operator did not want us to open it up with a Marlin spike to examine the interior.

The indications of a few of the broken wires that were visually apparent were buried in the rope noise. With the individual instrument tested, the gradual drift of the baseline of the loss-of-metallic-area channel would preclude detecting gradual wear trends, such as toward one extreme of the drum, unless multiple runs were made. On the other hand, more localized wear and corrosion losses would be readily apparent.

Tests were run on another crane at Port Hueneme with similar results.

Laboratory Tests at NCEL

Additional tests were performed in the laboratory at the Naval Civil Engineering Laboratory, Port Hueneme, California. Ideally, the instrument should be evaluated on a calibrated rope that was used in evaluating other instruments, including the MagnographTM, in a test track like that used in an earlier report.⁸ This test track could accommodate up to 2.5-inch-diameter ropes, operate at variable controlled speeds, and apply realistic operating tension to the rope using a hydraulic ram to position one pulley. (In contrast, most other rope test tracks in use in North America, which use bicycle wheels as sheaves, can only accommodate rope to one inch in diameter and can only apply a few pounds force to the rope.) Realistically calibrated ropes have been produced by carefully opening the rope and cutting internal or external wires with special tools. If the rope is then carefully closed up and run under tension through the test track, it will return to normal in both visual appearance and magnetic signature. (If the rope is not worked under tension, or if the operation is not performed carefully, the rope will appear splayed in that area and will give an anomalous magnetic signature.) Unfortunately, this facility has been dismantled.



FIGURE 2. PETTIBONE 50TK CRANE USED FOR EVALUATING THE LMA-75 AT PORT HUENEME, CA
(NOTE: THE ROPE OF THE 6-PART LINE ASSEMBLY WITH THE BLOCK AND TACKLE
WAS INSPECTED.)



FIGURE 3. THE LMA-75 IN PLACE ON A WIRE ROPE WITH THE INSTRUMENT HINGES OPEN

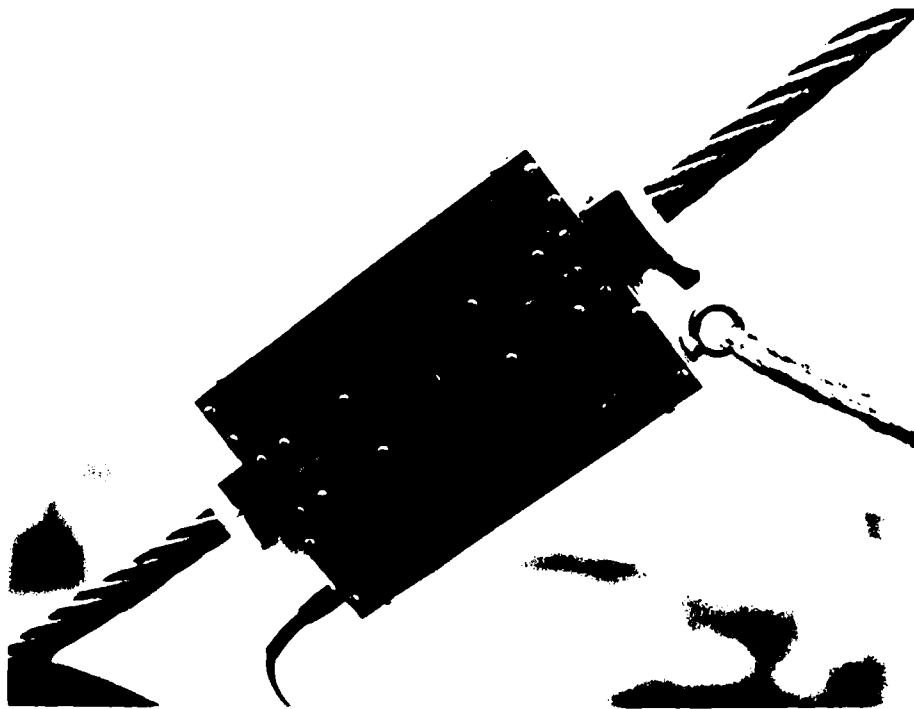


FIGURE 4. THE LMA-75 IN PLACE ON THE WIRE ROPE NEAR THE DRUM WITH THE INSTRUMENT HINGES CLOSED
(NOTE: THE ROPE TETHER (LOWER RIGHT) SAFELY HOLDS THE INSTRUMENT IN PLACE WHILE ALLOWING IT TO FOLLOW THE DRUM WINDINGS. ELECTRICAL CABLE EXITS THE INSTRUMENT AT THE BOTTOM OF THE PICTURE.)

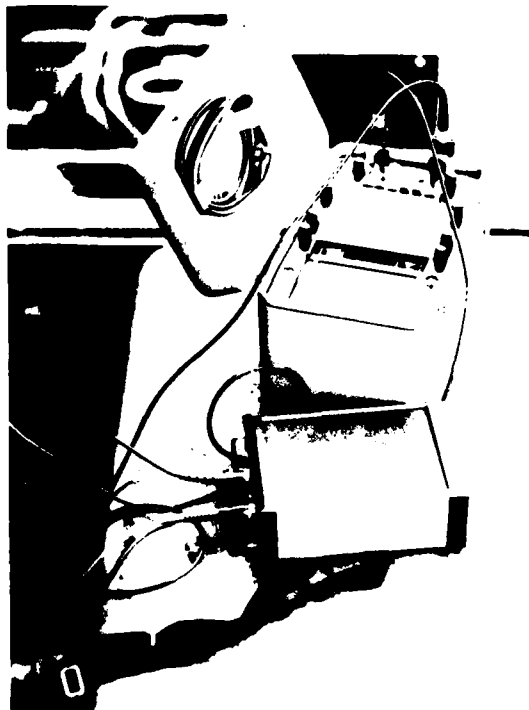


FIGURE 5. ELECTRONICS PACKAGE AND RECORDER IN PLACE ON THE CRANE HOUSING NEAR THE DRUM

This is believed to have been one of three facilities in North America that allowed laboratory testing of wire ropes under realistic loading, and the only one available to the U.S. Government for routine use.

The variation of response of the LMA-75 with azimuthal location of the defect was investigated. The rope used for this study was a section of new 6 x 19, 0.5-inch IWRC with a 3 x 16 wire core. One strand was carefully opened and a 0.25-inch-long section of identical wire inserted between the strand and the core; then the rope was carefully closed again.

This rope was held under enough tension to take up the slack as the LMA-75 was manually moved past the defect. The local fault signal was noted as tests were made with the defect at different azimuthal positions with respect to the opening plane of the instrument. The local fault signal was noted to vary by slightly more than a factor of three with orientation. Orientations were found that produced a defect signal so weak as to be only a factor of two greater than the rope noise. Dependence on azimuthal position of the defect has also been noted for the MagnographTM and other instruments.⁷

DISCUSSION

The LMATM series instruments indicate broken wires and localized loss of metallic area that is commensurate with heavier and bulkier instruments, while being easier and safer to handle in the limited platform space around the drums of cranes.

The responses of both the LMA-75 and competitive instruments have been noted to depend to some degree on the circumferential position of the defect. This asymmetry is expected to be less for interior flaws. Although it may result in an occasional broken wire being missed, this is not a serious objection to these machines because: (1) a few widely spaced broken wires will not render a rope unserviceable in most applications; (2) if two readings are taken (as with running the rope in both directions), the rope will usually have rotated with respect to the instrument and the defect will probably give a readable indication at least one time; (3) the rag technique will miss broken wires that are not fishhooked; and (4) these instruments respond to interior defects which the rag technique cannot detect, as well as exterior defects.

The expected application of the LMATM series of instruments (and other instruments such as the MagnographTM and the Rotesograph^{TM*}) is to survey the rope rapidly (at an inspection speed of 50 to 1000 feet/minute, as opposed to 6 feet per minute for safe operation with the rag technique). The inspector would then visually inspect suspect areas, possibly opening them with a Marlin spike, before pronouncing final judgment on the rope. All of these machines permit the initial survey of the rope to be conducted in less than a tenth of the time required by the rag technique and can greatly reduce the inspection-related downtime of hoists and cranes. The important differences between the LMATM series of instruments and those of their competitors (which are well-suited to mine hoists) are that the LMATM series instruments are compact, lightweight, and easy to handle on a crane platform. They will be used if inspectors and their management are made aware of their advantages. Their smaller size allows the loss-of-metallic-area readings to be pinpointed to a shorter length of rope.

Use of the magnetic tape recorder is strongly recommended, either by itself or in conjunction with a paper record. Individual defects can be studied using expanded scales on playback without continuing to tie up the crane. High quality data can be obtained that are not always attainable in the field because of problems with ink or thermal paper, and because of dirt and grease.

*Rotesco, Inc., Scarsborough, Ontario, Canada.

Some instruments incorporate a binary fault indicator that detects faults that exceed a selected threshold. The operator may be signaled by a light or by an audible alarm. The indications may also be displayed as a separate binary (on/off) trace or may be tabulated as a count of indications. Such binary fault indications can expedite surveying the rope for suspect areas.

Calibration procedures for these machines are needed so they may be adjusted to yield consistent readings in terms of absolute defect severity. These procedures should be simple to perform in the field. Training standards are also needed to familiarize the operator with modern wire rope considerations, principles of magnetic flux leakage inspection, and with the particular instrumentation being used. Both training and calibration standards are suggested in a current report.⁹

New wire rope inspection standards are needed to allow the inspectors to use these instruments in place of the rag test. Only by eliminating the rag can the inspection be speeded up and the hazards of the rag catching be eliminated. More realistic accept/reject criteria, which account for the fact that interior defects can now be detected, are needed. The old standards attempted to compensate for the hidden defects by putting more severe criteria on the number of visible defects allowed. If the old criteria are maintained, using these machines will only increase the rejection rate of wire ropes, a prospect not very appealing to economy-minded owners. Proper criteria can increase safety while reducing rejection rates.

This study has provided an independent assessment of the LMATM series instruments and pointed out their principal merits and weaknesses. Quantification of their performance vis-a-vis competitive instruments, such as the MagnographTM and the RotescographTM, would require operation on ropes that were dedicated to such testing, of known condition, and placed under realistic loading. For the sole purpose of comparing instruments, most operators will not permit an in-service crane rope to be spiked to expose its interior for defect verification. Comparative testing would also tie up an in-service crane for an excessive amount of time. Proper comparison of instruments is best done on a rope (or ropes) with calibrated defects using a test track that allows the loading of the rope to typical working tensions. Evaluations should be conducted on new calibrated ropes and on a calibrated rope with representative wear.

CONCLUSIONS

The LMATM series of wire rope inspection instruments is suitable for the detection of internal as well as external broken wires and local reductions in metallic area in wire ropes. The fact that its variation in sensitivity with azimuthal position may result in missing an occasional broken wire should not detract from its application in locating regions of broken wires for manual inspection and evaluation. (The rag technique would miss all of the broken wires if their fishhooks had been broken off, as could well be the case with the modern "high-strength," hardened plow steels.)

The baseline drift of the LMA channel would not mask relatively local variations, such as wear in the drum overlay regions. It could, however, mask wear that was preferentially at one or the other end of the cable, unless the operator astutely compared several runs.

The experiments conducted for this report were intended to provide an independent assessment of the LMATM series of instruments manufactured by NDT Technologies of South Windsor, Connecticut. Quantitative comparison with other instruments would require additional facilities. Such evaluation is not necessarily a priority effort since the optimum applications of these instruments seems to be different. The LMATM series of instruments appears to be ideally suited for inspection of the rigging of cranes. The instruments of this series are lightweight, compact, and easily manipulated in the tight quarters around the crane drum and rigging. Inspectors would be motivated to use these instruments rather than the heavier and larger instruments of other manufacturers, which are more suited for use on mine hoists. (Handling those larger instruments on the crane platform areas is a hazard in itself.)

Wire rope inspection standards must be revised to accommodate the more complete assessment of the condition of the wire rope afforded by the LMATM series of instruments and by other magnetic flux leakage instruments. The old rag inspection method should be scrapped for all inspections, since it is slow, dangerous, and prone to miss broken wires (especially on the new high-strength, hardened plow-steel wires, for which the margin for further work hardening is less).

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